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# An interactive severe weather activity to motivate student learning

## **Abstract**

An interactive Web-based severe weather activity has been developed at Iowa State University with broad applications to motivate student learning. The exercise uses an extensive archive of weather data emphasizing warm-season severe convective events and cold-season winter storms. Several variations of the activity have been developed based upon the meteorological background of students. The flexible design of the activity may allow for its use in K-12 settings, or as a significant training tool for weather forecasters outside the classroom.

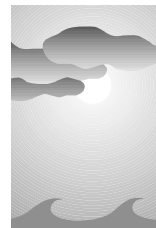
## **Disciplines**

Atmospheric Sciences | Geology

## **Comments**

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# An Interactive Severe Weather Activity to Motivate Student Learning



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## ABSTRACT

An interactive Web-based severe weather activity has been developed at Iowa State University with broad applications to motivate student learning. The exercise uses an extensive archive of weather data emphasizing warm-season severe convective events and cold-season winter storms. Several variations of the activity have been developed based upon the meteorological background of students. The flexible design of the activity may allow for its use in K–12 settings, or as a significant training tool for weather forecasters outside the classroom.

## 1. Introduction

A new paradigm of teaching based on constructivist theory holds that learners must construct an internal personal representation of knowledge. This new approach conflicts with the traditional methods where faculty present information that students are to memorize and recall (Johnson et al. 1991). Following this theory, since personal restructuring is required, knowledge cannot be transmitted. Rather, it must be constructed by an intellectually active learner striving to build a meaningful personal representation of experience.

A key to learning then is to provide a constructivist learning setting that closely resembles the real world so that context becomes part of the constructed knowledge and serves to enhance the utility of that knowledge, especially when applying it to new situations (Yarger et al. 1998). The term used for this learning setting is authentic. In this setting, complexity of the topic should be maintained to the greatest extent the learner's maturity permits. Complexity and authenticity maintain the structure of the material to be learned

and inherently provide reasons for knowing. An example of this approach is a forecast activity described in Yarger et al. (2000).

To help meet the goals of constructivist learning, a World Wide Web-based severe weather forecasting exercise using archived meteorological data has been developed at Iowa State University, which motivates student learning about the larger-scale weather patterns causing severe convective weather and disruptive winter weather. Severe weather was chosen to be the focus of the activity because most people find it interesting; many students interviewed at Iowa State University indicate that they select meteorology as a major at least partly as a result of a severe weather event.

Although well-designed traditional lab-based exercises can also meet the goals of constructivist learning, the work involved in creating these exercises can limit their number. Senior undergraduates in the meteorology program at Iowa State University have often commented on their desire to hone forecasting skills by making predictions for a large number of cases, and then comparing their forecasts with the actual weather that occurred. However, the work involved for an individual faculty member to (i) find appropriate cases demonstrating a specific situation, (ii) develop challenging questions relating to each case, and (iii) provide an overview of the meteorological aftermath can be prohibitive. This Web-based activity is designed to allow students access to an extensive (and constantly growing) dataset of cases,

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while minimizing the additional workload facing the instructor. Variations of the exercise have been created for use by students having different levels of meteorological background. The flexibility inherent in the exercise will permit its use in many settings outside the college classroom.

## 2. Design considerations

The severe weather forecasting exercise shares many of the design features using characteristics of the natural learning process (Schank et al. 1995) incorporated in an introductory meteorology course forecasting activity used since 1993 at Iowa State University (Yarger et al. 2000). For instance, the activity is

- goal directed (students are asked to name a state where they expect severe weather such as tornadoes, damaging wind and hail, flash flood-producing rain, advisory criteria freezing rain, wind chills below  $-35^{\circ}\text{F}$ , or storm total snowfall exceeding 6 or 12 in.),
- failure driven (students receive immediate responses to the answers they give for multiple-choice questions asked throughout the exercise, and they can reexamine the maps to reflect on the causes of their incorrect answers),
- case based (the instructor can choose specific cases that demonstrate well a certain atmospheric process that will be discussed in lecture), and
- learn-by-doing structured (students do what professionals do rather than merely reading about the subject, and use an archive of cases that is sufficiently large so that they can do the exercise 10–20 or more times in a semester).

Unlike the previous forecasting activity, which was originally designed to use current data for routine forecasting, this exercise directs students to make decisions about active or extreme weather, and relies entirely on archived data. This allows the instructor to restrict the forecast guidance available to students. For instance, students do not have the option of viewing National Weather Service forecasts for the events. In addition, only a limited number of model forecast maps are currently provided, and only for the warm-season convective events, where the coarse resolution of the models generally limits their use to providing guidance on the general larger-scale pattern.

The archiving of historical datasets for weather cases demonstrating specific atmospheric principles has long been a component of synoptic meteorology courses. The increased availability of computers for students in these courses in recent years has resulted in the development of some case study support materials [see, e.g., <http://www.comet.ucar.edu/resources/cases/index.htm> for products from the Cooperative Program for Operational Meteorology, Education and Training (COMET)], often in the form of raw data that must be accessed through other software. The Iowa State activity makes it easy for students to use the archived data, in that the data are displayed in user-friendly maps accessible from simple menus in the Web-based exercise (see Fig. 1a). Figure 1b shows a map of surface dewpoints and winds, valid at 1600 UTC, that would appear if this item was selected from the menu shown in Fig. 1a.

Another design consideration in the development of the exercise was flexibility for the instructor. Although the basic mechanism of map storage and presentation and flow of the exercise is the same for all versions of the activity, general questions that are asked for all cases can be input by the course instructor (or appropriate forecast office personnel) so that they best serve the needs of that group.<sup>1</sup> For instance, in Fig. 1a, students are asked to identify the type of front present in the southern plains. This question would be appropriate in an introductory course. An example of a question asked in the advanced version of the exercise used by senior meteorology majors can be seen in Fig. 2. Additional data, such as wind profiler observations and Eta Model output, are also made available to students in the advanced version of the exercise. For the warm-season convective events, the Eta output maps are 12-h forecasts valid at 0000 UTC, or around the time severe thunderstorms are often active. These maps can help the student estimate how the larger-scale weather features might evolve during the day; however, the small-scale nature of severe convection requires the student to go beyond mere mimicking of the model output. For the winter weather events, the Eta output is restricted to current or past times, so that it merely serves as additional analyses; no forecasts are provided.

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<sup>1</sup>An instruction manual is available at no charge from the corresponding author, and an administrative account is required in order to adjust questions and annotations.

In addition to flexibility in the level of questions, the instructor has the option to add case-specific questions that may apply for only one case. As an example, for a case where a large tornado occurs at a specific time, a question might appear in the hour before the event, asking a student to describe the surface wind fields in that region. For any question, the instructor can enter the answer and desired response that the student would receive for correct or incorrect answers, and can change these responses and answers at any time.

Both multiple-choice and short-answer questions are used in the exercise, and the instructor has the option to add or delete both types. Multiple-choice questions are designed so that students receive an immediate response indicating whether they are correct or not, along with pointers and links to educational sites. These multiple-choice questions are used both to maintain student interest and guide their analyses. Help topics are also listed at the top of the hourly exercise pages (see Fig. 1a). The student responses to short-answer questions are sent via electronic mail along with their multiple-choice results to the instructor. The number of short-answer questions asked will therefore depend somewhat on the time the instructor wishes to spend doing traditional grading.

In the following sections two versions of the exercise, representing short-term warm-season convective forecasting and longer-term winter storm forecasting, will be discussed in more detail.

### 3. Severe convective weather forecast activity

A large database of archived severe convective events was

developed in the summers of 1998 and 1999. The forecast exercise for these events is designed to begin around 1200 UTC, or early in the morning in the United States. Because most severe weather events occur in the late afternoon and evening hours, and are, therefore, a short-term forecasting issue, students are guided through this exercise hourly and answer questions throughout the morning. One idea underlying the design of the activity is to build upon the natural curi-

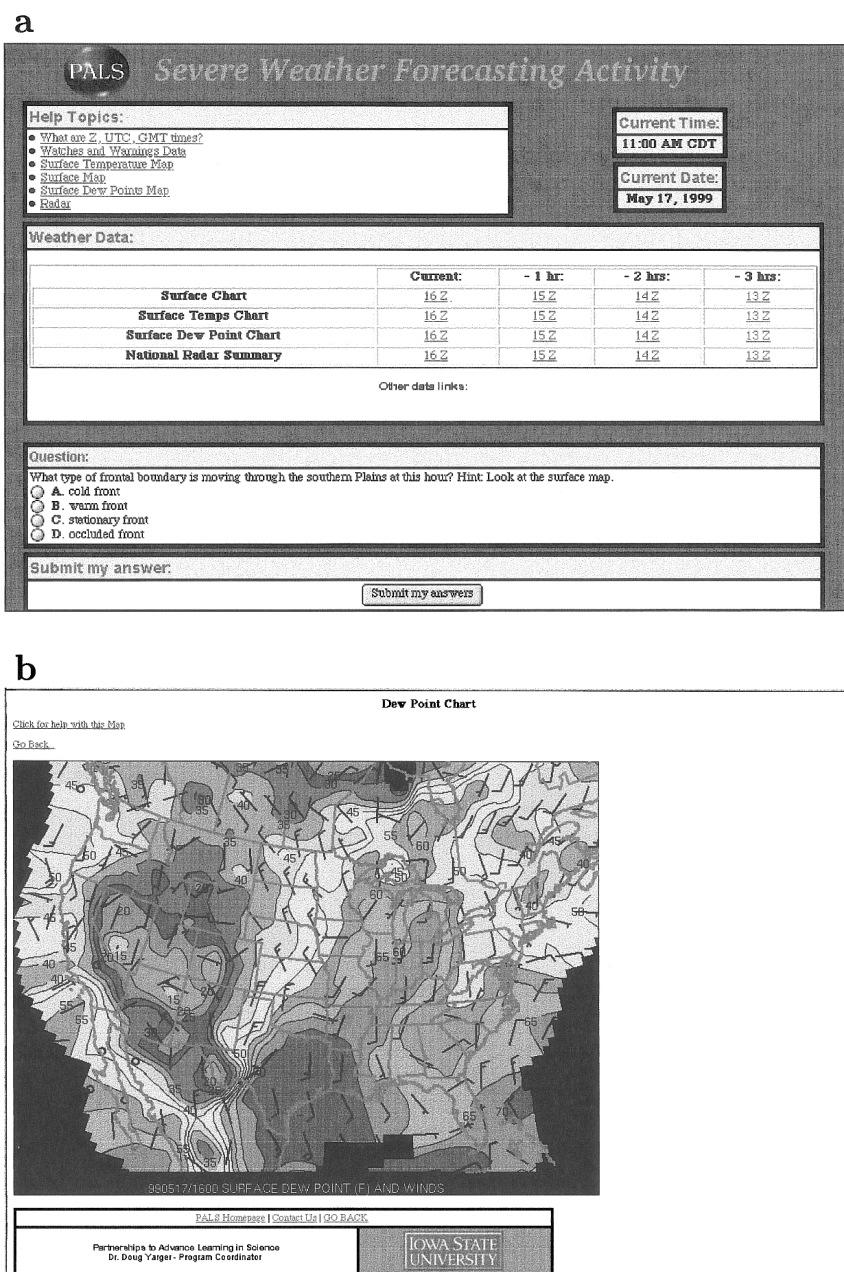


FIG. 1. Severe weather forecasting activity (a) introductory-level meteorology Web page appearing at 1600 UTC (1100 CDT) 17 May 1999, showing help topics, available weather data, and a question, and (b) surface dewpoint analysis valid at 1600 UTC. Winds are overlaid in (b), and a contour interval of 5°F is used.



- What are Z, UTC, GMT times?
- Watches and Warnings Data
- Surface Temperature Map
- Surface Map
- Surface Dew Point Map
- Radar
- ETA Forecast Maps

Current Time:

08:00 AM CDT

Current Date:

July 08, 1999

Available Weather Data:

	Current:	- 1 hr:	- 2 hrs:	- 3 hrs:	- 4 hrs:
Surface Chart	13 Z	12 Z	Missing	Missing	Missing
Surface Temps Chart	13 Z	12 Z	Missing	Missing	Missing
Surface Dew Point Chart	13 Z	12 Z	Missing	Missing	Missing
Moisture Divergence	13 Z	12 Z	Missing	Missing	Missing
National Radar Summary	13 Z	12 Z	Missing	Missing	Missing

Other data links:

[Precipitable Water](#)
[Lightning Data](#)
[Satellite Image](#)

Upper Air Data valid @ 12 Z

850 MB

700 MB

500 MB Vorticity

500 MB

300 MB

200 MB

Profiler Data valid @ 12 Z

1000 m Profiler

3000 m Profiler

9000 m Profiler

ETA Model Run @ 12 Z

Initial ETA CAPE

12 HR ETA Thickness and Pressure

12 HR ETA Vorticity

12 HR ETA Precipitation

Bonus Questions!!

Question 1:

Examine how 700 mb temperatures are changing upstream of Kansas City. What do these changes indicate with respect to severe weather potential:

☐ A. Cold advection is occurring which may help eliminate a cap  
☐ B. Warm advection is occurring, strengthening any cap and making severe weather less likely  
☐ C. Upward motion may occur, which could reduce or eliminate any cap, depending on the static stability  
☐ D. Either B or C  
☐ E. Advection is neutral

Submit my answer:

FIG. 2. Severe weather forecasting activity Web page appearing at 1300 UTC 8 Jul 1999, for upper-level meteorology use. Available weather data are shown, along with a question.

osity students have in severe weather events. The hour-by-hour progression is used to engage the participant in the anticipation and excitement of the development of severe weather. Although for meteorology majors, severe weather is normally but one part of their instruction, for nonmajors in an introductory meteorology course, severe weather may be the primary reason the course was taken, and the best opportunity available to engage students in scientific inquiry.

An example of a question used in the advanced version of the activity was shown earlier in Fig. 2. In this question, students are directed to examine 700-mb temperatures and reflect on what the field means regarding a cap that could prevent severe weather. The question is designed not only so that students state what they see on the maps, but also to force them to think about more complicated issues, such as the competing effects of warm advection and ascent (resulting in adiabatic cooling) on any cap. After a student answers a multiple-choice question, they immediately receive a response indicating how they did and are

permitted to take another look at the maps valid at that time. Students who answer questions incorrectly have indicated that they found it valuable to reexamine the maps to understand why they were incorrect. After answering each question, students also receive news and comments. This information may describe noticeable changes in the weather parameters during the last hour or indicate where significant weather has recently occurred.

At noon, a time usually preceding major severe weather events, students must organize the information they have seen and select from a clickable menu a state where they expect severe weather to occur before midnight. After selecting the state, the students must select a 3-h period (1200–1500, 1500–1800, 1800–2100, or 2100–0000 CDT) in which they expect the severe weather to occur. This option compels a student to seriously evaluate the weather situation on a given day. Will the cap be difficult to eliminate, delaying severe weather to late evening? Does the atmosphere seem ready to generate severe weather shortly

after the current noon hour? In addition to the time, students choose the types of severe weather, including tornadoes, severe criteria (damaging) winds and large hail, or rainfall sufficient for flash flooding (defined here to be 3 in.). Verification is based upon both reports in the *Storm Data* publication (from the National Climate Data Center) and local National Weather Service office bulletins.

During the hours after noon, students continue to answer a few questions that may cause them to second-guess earlier forecasts. It is during this time, when severe convective events generally initiate, that case-specific questions would be valuable. Students continue to receive “News and Notes” that help paint the picture of convective development and evolution. Many of the annotations contain highlighted terms that are links to explanations that a student can select to receive more information. The words squall line in a description of the weather in one region may bring to the screen a local radar image that depicts in great detail the squall line. From radar maps and these comments, students may begin to make conclusions about

how well their noon forecast is doing. At midnight, the exercise is completed, and the students are given the results of their forecast (Fig. 3). A map reveals the locations of the different severe weather criteria, which are also listed in a table. Students receive a score for their forecast, with 10 points received for each correct answer. A bonus score is added on, revealing their performance on the other questions (e.g., Fig. 2) asked during the exercise. These other questions encourage students to pay particular attention to data useful in diagnosing physical or dynamical processes that may strongly impact their forecast (such as capping inversions, vertical wind shear, cloud cover).

4. Winter storm activity

Because winter storms are also an important part of the climate in the United States, part of the exercise includes the forecasting of disruptive cold-season weather. Unlike convective events, forecasting issues

Forecast Results for May 17, 1999

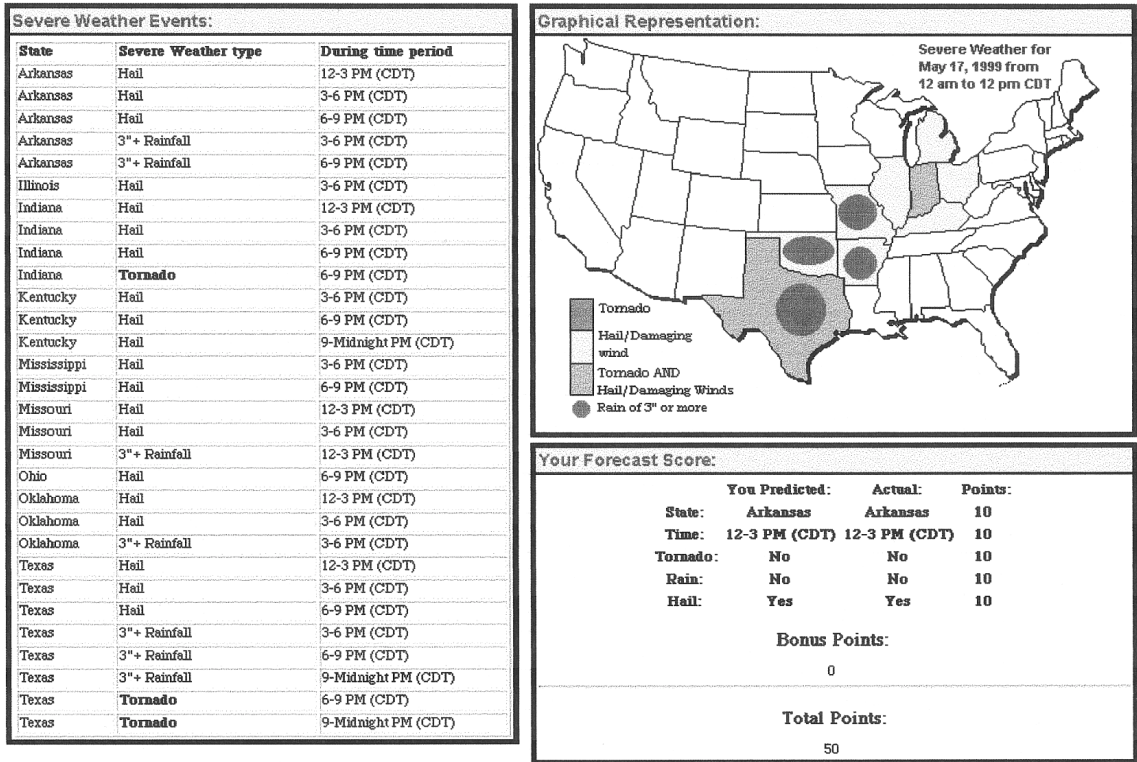


FIG. 3. Results page showing a student’s performance for the 17 May 1999 event. Severe weather occurrences are shown in tabular and graphical form.

National Radar Summary	00 Z	Missing	Missing	Missing	Missing
------------------------	------	---------	---------	---------	---------

Other data links:

**Upper Air Data valid @ 0 Z**

850 MB  
700 MB  
500 MB Vorticity  
500 MB  
300 MB  
200 MB

**Profiler Data valid @ 0 Z**

**ETA Model Data valid @ 0 Z**

ETA Thickness and Pressure  
ETA Vorticity  
ETA Precipitation  
ETA Model Temperatures

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**Question 1:**

Based on the data you've seen so far, name a state where substantial hazardous winter weather (6 inches or more of snow, advisory-criteria freezing-rain) may occur in the next 24 hours.

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**Question 2:**

What type of upper level feature is associated with the surface cyclone of interest?

☐ A. A negatively-tilted large-scale trough  
☐ B. A positively-tilted large-scale trough  
☐ C. A neutrally-tilted large-scale trough  
☐ D. A shortwave embedded within a large-scale ridge

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**Question 3:**

Examine the 850 mb temperature advection in the base of the trough of interest (as seen in the 500 mb map) associated with the surface cyclone. Which of the following is true:

☐ A. Significant cold advection will favor deepening of the upper-level trough  
☐ B. Warm advection will weaken the trough  
☐ C. Temperature advection is insignificant, so the trough should not deepen  
☐ D. All types of low-level temperature advection have no effect on the intensity of the upper-level trough.

---

**Submit my answer:**

Fig. 4. A portion of a winter storm forecasting activity Web page showing some available weather data, and three questions.

concerning winter storms generally occur over a longer time period in advance of the adverse weather. Thus, in the winter storm activity, students advance in time in 3-hourly intervals over periods that can span several days. Students are presented with notes, comments, access to weather maps, and questions every three hours. Typical questions in the advanced version of the winter storm activity can be seen in Fig. 4, along with the multiple-choice answers for questions 2 and 3. After an answer is submitted, a response page appears (Fig. 5), similar to the warm-season activity, that shows the student answer, the correct answer, and some discussion of why the question should be answered in a specific way. Weather data of potential use in understanding the answer are also available on this response page.

The winter storm activity can begin at any time during a case, since unlike warm-season convection, disruptive winter weather does not occur preferentially at any particular time during the day. After the first six hours of the activity, students must select a state, and type of disruptive winter weather, similar to the pro-

cess occurring at 1800 UTC in the warm-season exercise. The remainder of this exercise follows a similar pattern to the convective activity, with many opportunities for reinforcement of meteorological concepts.

## 5. Broader applications

Because some meteorological concepts are best revealed in individual cases, and general questions may not apply well, the exercise was designed to allow instructors great flexibility in tailoring it to suit their specific purposes. These design characteristics also facilitate the use of the activity outside a college-level course. Collaboration is currently under way at Iowa State University with education professionals to use the activity in K–12 education. In addition, some consultation has occurred with a local National Weather Service office on the use of the activity for forecaster self-improvement, or office training. In this type of professional setting, one person may take the role of instructor, and specific questions could be in-



put into the exercise. Answers would then be sent to that person, who might use them to determine topics for discussion. The large number of available cases might be useful to new hires who would want to gain confidence in their application of meteorological principles to different regional forecasting issues.

Work is also ongoing to expand the exercise to include forecasting of hurricanes and heat advisory events. In addition, new cases are constantly added as they occur. Additional links will be added within the annotations and responses allowing students to access a wide range of tutorials and simulations (Yarger et al. 1999), including such sources as the COMET training modules. An annotated instructor list describing the timing, location, and types of severe weather is already available for the cases; a search engine is being developed to allow users to select with ease cases demonstrating a specific weather phenomenon. The engine will search a case overview for each event to find the terms selected. This feature should permit easy use of the activity in a range of different meteorological courses. In addition, work is also ongoing to allow

National Weather Service warnings (tornado, severe thunderstorm, flash flood) to scroll across the screen in the convective exercise at the appropriate hours in regions where the students had forecasted severe weather to occur.

## 6. Discussion

A flexible Web-based severe weather activity has been designed to promote student-motivated learning. Students may access a large number of historical cases in the exercise and are able to view numerous maps to assist in answering questions and forecasting the occurrence of severe weather. A warm-season convective exercise exposes students to short-term forecasting concerns and requires the forecasting of tornadoes, severe winds or large hail, and flash flood-producing rainfall. A winter storm activity spans a longer time period per case and requires students to forecast the occurrence of heavy snowfall, advisory criteria freezing rain, and dangerous wind chills.

### Question Response

Question 1:  
Your Text response was entered and will be sent to Dr Gallus.

Question 2:  
**You answered Incorrectly:**  
*You were asked =>* What type of upper level feature is associated with the surface cyclone of interest?  
*You responded =>* C. A neutrally-tilted large-scale trough  
*The Correct answer was =>* D. A shortwave embedded within a large-scale ridge  
*Dr Gallus's response =>* Good try, but this is more of a case of a shortwave trough passing through a larger-scale ridge. Many storm systems begin with a short wave trough passing through a ridge. As the system develops, or the shortwave trough moves past the ridge, a larger-scale trough will become easier to see.

Question 3:  
**You answered Incorrectly:**  
*You were asked =>* Examine the 850 mb temperature advection in the base of the trough of interest (as seen in the 500 mb map) associated with the surface cyclone. Which of the following is true:  
*You responded =>* B. Warm advection will weaken the trough  
*The Correct answer was =>* C. Temperature advection is insignificant, so the trough should not deepen.  
*Dr Gallus's response =>* The best answer here is probably (C) - no significant temperature advection. There is some weak cold advection, but the flow is very weak in this region, and thus this forcing would not favor rapid deepening of the storm system.

#### Weather Data:

	Current:	- 3 hr:	- 6 hrs:	- 9 hrs:	- 12 hrs:
Surface Chart	00 Z	Missing	Missing	Missing	Missing
Surface Temps Chart	00 Z	Missing	Missing	Missing	Missing
Surface Dew Point Chart	00 Z	Missing	Missing	Missing	Missing
Moisture Divergence	Missing	Missing	Missing	Missing	Missing
National Radar Summary	00 Z	Missing	Missing	Missing	Missing

Other data links:

Upper Air Data valid @ 0 Z  
850 MB  
700 MB  
500 MB Vorticity

Profiler Data valid @ 0 Z

ETA Model Data valid @ 0 Z

FIG. 5. Responses appearing after question in Fig. 4 is answered.

The goal-directed exercise provides numerous opportunities to guide students toward reinforcing material supporting course concepts, and immediate feedback on multiple-choice answers provides information at the time students are prepared to learn. The exercise allows students pursuing forecasting careers a large number of cases with which to experiment and many opportunities to do better on another day.

The flexible design of the exercise facilitates its use from K–12 educational settings to undergraduate and graduate programs. It also can be used in operational meteorology settings, where an office member may assume the role of instructor, input the questions most appropriate to the facility, and receive the answers from colleagues. The exercises can be accessed via the Internet ([http://www.pals.iastate.edu/svr\\_frst/index.html](http://www.pals.iastate.edu/svr_frst/index.html)).

Because the exercise was only recently implemented at Iowa State University (in the fall semester of 1999), there has been limited opportunity to quantitatively evaluate the impact on student learning. Fullan (1993) and Reeves and Okey (1996) have shown that some measures of impact such as achievement tests (which could be performed shortly after implementation) are poorly matched to the goals of activities like the one described here. Instead, constructivist activities such as this one have their greatest benefit in long-term retention or application of material (Lehrer 1993). The longitudinal studies typically used to document long-term impact are beyond the scope of this project. What can be said at this time is that students have been enthusiastic about the activity and already have offered much constructive feedback. For instance, one student recommended that the forecast maps be made easily accessible when the answers to a question appear, so that students can immediately check the data to better understand what they did wrong when they answer incorrectly. This suggestion was implemented. Many other students

have indicated that they enjoyed doing the exercises and intended to do other cases on their own. Interested persons are encouraged to use the activity and provide feedback that will improve it as a community resource.

*Acknowledgments.* Much of the data collection for this activity was performed by undergraduates at Iowa State University. Special thanks are given to Brad Ross, Jason Alumbaugh, Tiffany Raisch, and Jared Anderson for their efforts. The constructive comments of three anonymous reviewers were helpful. This work was sponsored by National Science Foundation Grant DUE9752635.

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